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(71) Applicant: Xerox Corporation
Rochester, New York 14644 (US)

(72) Inventor: Fan, Zhigang
Webster, New York 14580 (US)

(74) Representative:
Grünecker, Kinkeldey,
Stockmair & Schwanhäusser
Anwaltssozietät
Maximilianstrasse 58
80538 München (DE)

(54) Digital imaging method and apparatus for detection of document security marks

(57) The present invention provides in one aspect a method of digitally processing images, comprising the steps of: potentially including in a printed document a security mark defined by a plurality of actual mark constituents, processing the image data to identify potential constituents, for each potential mark constituent represented by said digital image data, determining if said potential mark constituent, together with at least one other potential mark constituent represented by said digital data, defines a potential security mark, and, for each potential security mark represented in said digital image data, determining if said potential security mark represents an actual security mark present in said printed document. In a second aspect there is provided a digital image processing method for preventing unauthorized reproduction of a printed document. In a third aspect there is provided a method of processing digital image data representing a color printed document that includes a security mark.

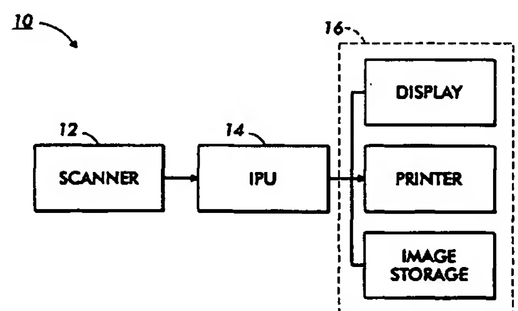

FIG. 1

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Description

[0001] The proliferation of digital image processing systems, such as digital color copiers, that are able to make very high quality reproductions or "copies" of color documents at a low cost has led to use of these machines by criminals for reproduction of currency, checks, stock certificates, legal documents, and other printed documents not legally reproducible. Obviously, any reproductions of these documents are counterfeit and illegal. Unfortunately, there has heretofore not been found a method or apparatus for effectively and efficiently detecting the attempted reproduction of currency and the like so that the reproduction may be thwarted. Without an effective an efficient method/apparatus for detecting currency and other non-reproducible documents, criminals have often been able to produce counterfeit documents almost at will.

[0002] Many difficulties are presented during the attempted identification of a security mark in a printed document. The documents, such as currency, are often significantly worn. Also, the document may be placed in the reproduction apparatus at an irregular angle or location that renders detection of the security mark more difficult. Also, improper or erroneous detection of a security mark, and any resulting operations to prevent duplication of the document, are likely to upset and inconvenience those attempting to make legitimate reproductions. Accordingly, erroneous detection of a security mark in a document must be minimized.

[0003] In accordance with the present invention, a new and improved digital imaging method and apparatus are provided for effective and efficient detection of document security marks to prevent counterfeiting of documents.

[0004] In accordance with a first aspect of the present invention, a method of digital image processing is provided. The method includes, for a printed document potentially including a security mark defined therein by a plurality of actual mark constituents each having a select color, size, and shape and having a select spatial arrangement relative to each other, scanning the document to obtain digital image data corresponding to the printed document, the digital image data defined in terms of a plurality of color input pixel values. The digital image data is processed to identify all portions representing potential constituents of a security mark. For each potential mark constituent represented by the digital image data, it is determined if the potential mark constituent, together with at least one other potential mark constituent represented by the digital image data, defines a potential security mark. For each potential security mark represented in the digital image data, it is determined if the potential security mark represents an actual security mark present in the printed document.

[0005] In accordance with another aspect of the present invention, a digital image processing method for preventing unauthorized reproduction of a printed document including a security mark defined in terms of a plurality of actual mark constituents having a select color, select dimensions and arranged in a select pattern relative to each other, includes scanning said printed document to derive color digital data representing the printed document, the color digital data defined in terms of a plurality of pixels each having a color value. All pixels of the color digital data having a color value representing a color at least approximating the select color of the plurality of actual mark constituents are identified. A binary map of the color digital data is constructed and defined in terms of "on" and "off" pixels, the "on" pixels corresponding to the identified pixels of the color digital data having color values at least approximating the select color of the plurality of actual mark constituents. The binary map is used to identify potential mark constituents defined by the "on" pixels and to identify at least one neighborhood of plural potential mark constituents together defining a potential security mark. The potential security mark is identified as an actual security mark if the potential mark constituents thereof are uniform relative to each other. If an actual security mark is identified, effective duplication of the printed document is prevented.

[0006] In accordance with still another aspect of the present invention, a method of processing digital image data representing a color printed document that includes a security mark for purposes of identifying the security mark represented in the digital image data includes processing the digital image data to identify all portions thereof defining a select color corresponding to the color of the security mark in the printed document. For each portion of the digital image data defining the select color, it is determined if the portion represents a potential constituent of a security mark in the printed document. The method further includes, for each potential security mark constituent identified in the digital image data, determining if the potential security mark constituent, together with at least one other potential security mark constituent, defines a potential security mark. The potential security mark constituents defining each potential security mark are compared to each other to determine if they are uniform in terms of color and size relative to each other. A potential security mark is identified as a security mark represented in the digital image data if the potential security mark constituents of the potential security mark are sufficiently uniform in terms of the least color and size relative to each other.

[0007] In accordance with another aspect of the present invention, a document reproduction security method includes scanning a printed document to derive color digital image data representative of the printed document. The digital image data is processed to identify all pixels thereof in a select color range used to define a security mark in the printed document. The digital image data is also processed to identify all connected components comprising only pixels of the digital

image data in the select color range. The digital image data is processed to identify, as potential mark constituents, all of the connected components having both a size and shape corresponding to a predefined size and shape of actual mark constituents defining the security mark in the printed document. The digital image data is further processed to establish a neighborhood of a select size about each potential mark constituent and to identify, as a potential security mark, all neighborhoods comprising: (i) a number of potential mark constituents greater than or equal to a minimum and less than or equal to a maximum number of actual mark constituents required to define a security mark; and (ii) potential mark constituents arranged relative to each other in a manner corresponding to the actual mark constituents defining the security mark in the printed document. For each neighborhood identified as a potential security mark, the digital image data is further processed to identify the potential security mark as an actual security mark if the potential mark constituents in the neighborhood are uniform in terms of at least size and color. Effective reproduction of the printed document is prevented if the digital image data includes an actual security mark.

[0008] One advantage of the present invention is the provision of a digital imaging document security mark detection method and apparatus that effectively and efficiently detect document security marks upon attempted digital reproduction of a printed document including a security mark to prevent production of counterfeit documents.

FIGURE 1 is a block diagram illustrating an image processing system in accordance with the present invention;

FIGURE 2A illustrates a printed document such as a currency note, including a security mark;

FIGURES 2B and 2C show enlarged portions of the document illustrated in FIGURE 2A for purposes of showing the features of the security mark;

FIGURE 3 is a flow-chart illustrating an overall digital image processing method for detecting document security marks in accordance with the present invention;

FIGURE 4 is a more detailed flow-chart illustrating a digital image processing method of detecting document security marks in accordance with the present invention;

FIGURE 5A is a flow-chart illustrating the binarization step of a digital image processing method for detection of document security marks in accordance with the present invention;

FIGURE 5B illustrates the binary data resulting from application of the binarization method of FIGURE 5A to the digital image data obtained from the printed document of FIGURE 2A;

FIGURE 6A is a flow-chart illustrating the micro-detection step of a digital image processing method for detecting document security marks in accordance with the present invention;

FIGURE 6B diagrammatically illustrates a method of identifying connected components of binary image data in accordance with the present invention;

FIGURE 6C diagrammatically illustrates evaluation of connected component size in accordance with the present invention;

FIGURE 6D diagrammatically illustrates a connected component template matching operation in accordance with the present invention;

FIGURE 6E illustrates the portions of the binary image data of FIGURE 5B that correspond to potential constituents of a security mark in the printed document of FIGURE 2A;

FIGURE 7A is a flow-chart illustrating a macro-detection operation of a digital image processing method for detecting document security marks in accordance with the present invention;

FIGURE 7B illustrates the portions of the binary image data of FIGURE 5B that correspond to potential security marks in the printed document of FIGURE 2A;

FIGURE 8 illustrates a verification operation of a digital imaging method for detecting document security marks in accordance with the present invention; and,

FIGURE 9 is a flow-chart illustrating control of the digital image processing system to prevent effective duplication of a document including a security mark.

[0009] A digital image processing system **10** in accordance with the present invention is shown in FIGURE 1. An image input scanner **12** derives and delivers digital image data in the form of one or more monochromatic separations, wherein the picture elements or pixels of each separation are defined at a depth of d bits per pixel where d is an integer. Accordingly, each pixel of each separation is defined in terms of d bits per pixel (bit depth = d), and each pixel has some gray value between full off and full on. When the digital image data is provided in terms of a single monochromatic separation, the image is monochromatic, for example, so called black-and-white image data. On the other hand, when the digital image data is provided in terms of two or more monochromatic separations, a color image results when the data from the separations is combined, for example, red-green-blue (RGB) separations or cyan-magenta-yellow (CMY) separations.

[0010] The image signals are input from the scanner **12** to an image processing unit **14** wherein digital image processing, such as security mark identification in accordance with the present invention, is performed. The image processing unit **14** may be provided by any suitable electronic computing apparatus such as an electronic computer, a dedicated electronic circuit, or

any other suitable electronic circuit means. The image processing unit **14** outputs data in a suitable format to an image output terminal **16** such as a digital printer and/or visual display. Suitable apparatus for digital image input and/or output include the XEROX Document Center 265DC digital imaging system, Pixelcraft 7650 Pro Imager Scanner, XEROX DocuTech Production Printing System scanners, the XEROX 5775 digital color copier, the XEROX 5760 and 5765 Majestik digital color copiers, or any other suitable color digital scanner/copier. Regardless of the depth d at which each pixel is defined, the location of each pixel in each separation bitmap is also defined, typically in terms of a row "n" and a column "m."

[0011] Figure 2A illustrates a currency note including a security mark imprinted or otherwise included thereon. The illustrated currency note and security mark are for ease of illustrating the invention only, and those of ordinary skill in the art will recognize that the invention is equally applicable to any type of document including any suitable security mark thereon. As noted, checks, stock certificates, bonds, and legal documents are some other examples of documents that may include security marks and that may, consequently, be protected from unauthorized reproduction according to the present invention.

[0012] The currency note **20** is printed on paper **22** or other suitable substrate and comprises various markings, such as denomination markings **24**, text **26**, various decorative images and designs **28**, and a security mark **SM** used to identify the currency note **20** as an authentic document. As illustrated and described herein, the security mark **SM** is printed in the same or similar manner on the document **20** as the information **24, 26, 28**, typically using any suitable color ink.

[0013] With reference now to FIGURES 2B and 2C, the portion of the currency note **20** including the security mark **SM** is illustrated and greatly enlarged to show the characteristics of the security mark **SM** used in the present example. As noted, in practice, the security mark will likely take any one of a wide variety of alternative forms, and the invention is not to be limited to the illustrated or any other particular security mark. In the present example, the security mark **SM** is defined on the note **20** (according to a definition promulgated by the appropriate authorities) by three identical mark constituents **MC**, each having identical size, shape and color according to the security mark definition. Also, the mark constituents **MC** are arranged in a select pattern or arrangement as required by the definition of the security mark **SM**. As illustrated herein, the mark constituents **MC** are circular and arranged at the vertices of a right triangle. The mark constituents **MC** are separated from each other by the distances **D1, D2, D3**, to define the security mark **SM** further as having a select overall size and shape.

[0014] The apparatus and method in accordance with the present invention operate the image processing unit **14** to detect the existence of a security mark **SM** in a document such as the note **20** scanned by the image input scanner **12** so that the image processing unit can prevent or inhibit unauthorized reproduction of the note **20** or other document being scanned. Those of ordinary skill in the art will also recognize that the subject method hand apparatus may be used to determine the authenticity of a document.

[0015] With reference now to FIGURE 3, a preferred digital image processing method for detection of document security marks is illustrated in accordance with the present invention. The security mark detection method as implemented using the digital imaging processing system **10** comprises: **S1** - obtaining a digital input image, typically through use of the image input scanner **12**; **S2** - binarization of the digital input image; **S3**- micro-detection; **S4** - macro-detection; **S5** - verification; and **S6** -prevention of the effective reproduction of the input document if a security mark is found. The operations **S2** through **S6** are preferably carried out in the image processing unit **14**.

[0016] The operations **S1-S6** are illustrated in further detail in FIGURE 4. The step **S1** comprises scanning an input printed document, such as the currency note **20**, using the input image scanner **12** to derive color digital image data in terms of multiple color separations in a suitable color space, e.g., red R, green **G**, blue **B**, or the like. The scanner **12** may derive or deliver the digital image data in terms of any other suitable color space.

[0017] The binarization step **S2** comprises a first sub-step **S2a** of identifying all pixels in the input digital image as derived by the scanner **12** having or representing a color in a select range. A second sub-step **S2b** constructs a bitmap corresponding to all pixels of the input digital image identified as having a color in the select range.

[0018] The micro-detection operation **S3** comprises sub-steps **S3a-S3c**. More particularly, using the bitmap derived from the binarization operation **S2**, "connected components" in the bitmap are determined **S3a**, and those of a size or shape not corresponding to a mark constituent **MC** are discarded **S3b**. Remaining connected components are identified as potential mark constituents **S3c**.

[0019] In the macro-detection operation **S4**, potential mark constituents in neighborhoods of other potential mark constituents that are over-populated or under-populated relative to a number of mark constituents **MC** defining a security mark **SM** are disregarded **S4a**. All remaining potential mark constituents tat are not properly spaced from or arranged relative to their neighbor potential mark constituents are also disregarded **S4b**, and only those still remaining are identified as potential security marks **S4c**.

[0020] Thereafter, all potential security marks are further analyzed for uniformity, e.g., uniformity of color, uniformity of size, and those that are not sufficiently uni-

form are discarded **S5a**. Any remaining potential security marks are positively identified as actual security marks **SM**. If an actual security mark **SM** is identified, the image processing unit **14** prevents effective duplication of the document scanned on the image input scanner **12**, e.g., by completely terminating the digital image processing operation, by inserting a "VOID" message or the like in the output data sent to the image output device **16**, or by otherwise failing to output an exact replica of the input document, such as the currency note **20**.

[0021] The operations **S1-S6** will now be described in further detail with reference to the currency note **20**. In accordance with the operation **S1**, the currency note **20** is scanned to obtain digital image data representing same in a suitable color space. This digital image data is fed to the image processing unit **14** for carrying out the operations **S2-S6** in accordance with the present invention.

[0022] With reference to FIGURES 5A and 5B, the binarization operation **S2** comprises constructing a bitmap **30** defined by a plurality of pixels corresponding respectively in location to the plurality of pixels defining the input digital image of the currency note **20**. To construct the bitmap **30**, the color of each pixel defined by the input digital image is examined by the sub-step **S2a** to identify each pixel having a color in a select range corresponding to the color used for the actual mark constituents **MC** in the security mark **SM**. For each pixel of input image data in the proper color range, a sub-step **S2b-1** sets the correspondingly located pixel in the bitmap to 1 or "on." All other pixels in the bitmap are set to 0 or "off" by the sub-step **S2b-2**. Of course, an initialization sub-step may alternatively be used to set all pixels in the bitmap **30** "off" prior to the color-checking sub-step **S2a**. Using the binary digits "1" and "0" to represent "on" and "off" conditions corresponds with conventional computer science notation. Of course, the binary digits "0" and "1" may alternatively represent "on" and "off" respectively, and the invention is not intended to be limited to either notation.

[0023] Those of ordinary skill in the art will also recognize that many different methods exist for determining if a color of a pixel defined by values selected from a particular color space falls within a select color range, i.e., whether the color defined for a pixel in a particular color space is "close enough" to a desired color. If the distance of the actual color from the desired color is greater than a color range threshold **T**, then the actual color is outside of the range and not "close enough" to the desired color. For example, if the pixels of the input digital image representing the currency note **20** are each defined by the actual red, green, and blue values (R,G,B), and if a pixel of a desired color is defined by desired red, green, blue values (R', G', B'), then the distance of the color defined by the actual red, green, blue values R,G,B from the desired color defined by the red, green blue values (R',G',B') may be calculated and compared to the threshold **T** according to:

$$T \geq \sqrt{(R-R')^2 + (G-G')^2 + (B-B')^2}$$

Of course, those of ordinary skill in the art will recognize that alternative methods exist for determining whether a color value of a pixel of a digital image is within a select color range. The preferred method will vary depending upon the particular color space by which the pixel is defined. It is not intended that the present invention be limited to any particular color comparison method or any particular color space.

[0024] Referring now more particularly to FIGURE 5B, the bitmap **30** resulting from binarization **S2** of the input digital image derived by the scanner **12** for the currency note **20** is illustrated. For each pixel of the input digital image derived by the scanner that represents a color in a select color range encompassing the color used to print the security mark **SM**, the bitmap **30** is defined by a correspondingly located "on" pixel. One or more of these "on" pixels are generally identified at **34** in FIGURE 5B. Likewise, all other pixels defining the bitmap remain or are set to an "off" condition. These "off" pixels are collectively identified at **32** in FIGURE 5B. Accordingly, the bitmap **30** includes or identifies only those pixels from the input digital image that represent a color in the select color range that approximates the actual color of the constituents **MC** of the security mark **SM**.

[0025] The bitmap **30** is further processed according to the micro-detection operation **S3** as illustrated in FIGURES 6A-6D in accordance with the present invention. A first sub-step **S3a** identifies all "connected components" in the bitmap **30**. The operation of identifying connected components, by itself, from digital image data such as the bitmap **30** is a conventional operation and well known to those of ordinary skill in the art of digital image processing, in particular, the art of optical character recognition (OCR). In the preferred embodiment illustrated herein, connected components in the bitmap **30** are identified as illustrated in FIGURE 6B. Each "on" pixel **34** of the bitmap **30** is placed in the center cell **38** of a 3x3 pixel matrix **36**. All other "on" pixels **34** encompassed in the matrix **36** are deemed to be part of the connected component **CC** including the pixel **34** in the central matrix cell or location **38**. Therefore, each connected component **CC** of the bitmap **30** comprises a single "on" pixel **34** or a group of "on" pixels **34**, wherein the pixels defining the group are each immediately adjacent to at least one other pixel in the group.

[0026] Once each connected component **CC** in the bitmap **30** has been identified, each connected component **CC** is further examined by sub-steps **S3b-1**,**S3b-2** to determine if the connected component is a potential mark constituent. Referring also now to FIGURE 6C, the sub-step **S3b-1** performs a size-checking operation on each connected component **CC** to determine if either its column width **X** or row height **Y** either (1) exceeds or (2)

fails to meet the size of a mark constituent **MC**. If the connected component **CC** under consideration by the sub-step **S3b-1** is too large or too small in either dimension, it is bypassed. Preferably, the size checking sub-step **S3b-1** compares the width/height dimensions of each connected component **CC** to acceptable width/height size ranges rather than a select fixed value to account for printing, scanning, and other variations.

[0027] Each connected component **CC** that satisfies the size requirements of the sub-step **S3b-1** must also survive a template-matching sub-step **S3b-2** wherein the connected component **CC** is compared to and must match at least one template of an actual mark constituent in order for the connected component to be deemed a potential mark constituent b. This template-matching operation is diagrammatically illustrated in FIGURE 6D. Both of the connected components **CC1** and **CC2** satisfy the size checking sub-step **S3b-1**. Thus, each is then compared to a template **40** including a plurality of cells **42**. Certain cells **42** of the template **40** are target cells **44**, arranged in the shape and size of a mark constituent **MC**. In order for a connected component **CC1,CC2** to match a template, the template is overlaid with the connected component, and at least a select percentage of the target cells **44** must match or correspond to the pixels **34** defining the connect component **CC1,CC2**. Again, to account for printing, scanning, and other variations, a perfect template match is preferably not required. In FIGURE 6D, the connected component **CC1** matches the template **40**, while the connected component **CC2** does not. Accordingly, the sub-step **S3c** identifies only the connected component **CC1** (and all other connected components that satisfy the template-matching operation **S3b-2**) as a potential mark constituent **PMC** as illustrated in FIGURE 6E.

[0028] Referring now to FIGURES 7A and 7B, the bitmap **30** is further processed according to the macro-detection operation **S4** in an effort to determine which, if any, of the potential mark constituents **PMC**, with other potential mark constituents, defines a potential security mark **PSM**. As noted with reference to FIGURE 2C, an actual security mark **SM** is defined by actual marked constituents **MC** arranged in a specific pattern and spaced from each other by the distances **D1,D2,D3**.

[0029] Using this information, which is obtained from the definition of the security mark **SM**, and for each potential mark constituent **PMC**, the sub-step **S4a-1** establishes a neighborhood about the potential mark constituent having a radius equal to or minimally larger than the maximum of the distances **D1,D2,D3**. A sub-step **S4a-2** determines the number of potential mark constituents **PMC** in the neighborhood, including the central or main potential mark constituent about which the neighborhood is established. The sub-step **S4a-2** compares the number of potential mark constituents in the neighborhood to the number required to define a security mark. If a neighborhood has too many or too few potential mark constituents compared to the number required to define a security mark, a sub-step **S4a-3** disregards or bypasses the potential mark constituent about which the neighborhood is based, and another potential mark constituent **PMC** is examined beginning at the sub-step **S4a-1**.

[0030] On the other hand, if the neighborhood established about a potential mark constituent **PMC** comprises the number of potential mark constituents required to define a security mark **SM**, the neighborhood is further examined by the sub-step **S4b-1**. Preferably, to account for the presence of "noise" potential mark constituents **PMC**, a neighborhood with one or two extra potential mark constituents relative to the number required to define a security mark **SM** is deemed to satisfy the sub-step **S4a-2** so as to be further processed by the sub-step **S4b-1** rather than discarded.

[0031] For neighborhoods having an acceptable number of potential mark constituents **PMC**, the sub-step **S4b-1** determines the distances between each potential mark constituent and its neighbors. The sub-step **S4b-1** then compares these distances to the predefined distances **D1,D2,D3** of the security mark **SM**. The distances between potential mark constituents **PMC** in a neighborhood must equal or be a super-set of the distances **D1,D2,D3** plus or minus a margin of error to account for printing, scanning, or other variations. If not, the sub-step **S4a-3** disregards or bypasses the potential mark constituent **PMC** about which the neighborhood is based, and the next potential mark constituent is examined beginning with the sub-step **S4a-1**.

[0032] However, if the distances between potential mark constituents **PMC** in a neighborhood equal or are a super-set of the distances **D1,D2,D3**, a sub-step **S4b-2** discards any noise potential mark constituents **PMC** in the neighborhood and determines the position of the remaining potential mark constituents **PMC** in the neighborhood relative to each other and compares same to the relative position of the mark constituents **MC** defining an actual security mark **SM**. More particularly, the sub-step **S4b-2** identifies and then discards noise potential mark constituents **PMC** from a neighborhood based upon the distances determined by the sub-step **S4b-1**. Any potential mark constituents **PMC** not relevant to the result of obtaining the distances **D1,D2,D3** is deemed to be noise and discarded.

[0033] The sub-step **S4b-2** determines the relative positions of the potential mark constituents **PMC** in a neighborhood, and compares same to the security mark **SM** using any other wide variety of methods. A preferred method, which operates independent of any rotation or other shift due to scanning variations at the image input scanner **12** is to use the distances as determined by the sub-step **S4b-1**. In such case, the potential mark constituents **PMC** in the neighborhood are examined to determine if the distances separating the potential mark constituents are arranged in the same sequence as the distances **D1,D2,D3** of a security mark **SM**. Such a method operates independently of the vertical, lateral,

or rotational placement of the potential mark constituents **PMC** in the bitmap **30**. By way of example, two neighborhoods **50,52** (FIGURE 6E) of potential mark constituents **PMC** satisfy the distance requirements of the sub-step **S4b-1**. However, when the sub-step **S4b-2** examines the relative positions of the potential mark constituents **PMC** of each neighborhood **50,52**, only the neighborhood **50** satisfies the requirement that the potential mark constituents **PMC** be positioned relative to each other as illustrated in FIGURE 2C - with the distances **D1,D2,D3** encountered sequentially when the potential mark constituents **PMC** are examined in a clockwise order. In an alternative embodiment, each potential security mark **PSM** is matched against a series of security mark templates, wherein the templates are devised so that, if the potential security mark represents an actual security mark, one template will be matched regardless of any rotational shift of the constituents of the potential security mark - i.e., the entire potential security mark will be compared to a template of an actual security mark, wherein the templates encompass every possible rotational arrangement in which the constituents of the potential security mark could define an actual security mark.

[0034] If a neighborhood does not satisfy the sub-step **S4b-2**, the sub-step **S4a-3** bypasses the potential mark constituent **PMC** about which the neighborhood is established and another potential mark constituent **PMC** is processed beginning with the sub-step **S4a-1**. On the other hand, if a neighborhood satisfies the sub-step **S4b-2**, the sub-step **S4c** identifies the neighborhood as a potential security mark **PSM** (FIGURE 7B), and processing in accordance with the macro-detection operation **S4** continues at **S4a-1** for the next potential mark constituent **PMC** not already part of a potential security mark **PSM**.

[0035] If the macro-detection operation **S4** results in the identification of any potential security marks **PSM**, processing continues with a verification operation **S5** in accordance with the present invention as illustrated in FIGURE 8. Because the binarization **S2**, micro-detection **S3**, and macro-detection **S4** operations all preferably rely upon "ranges" or otherwise allow some variation in connection with the identification of potential mark constituents and potential security marks in terms of color, size, shape, and the like, it is possible that one or more of the potential mark constituents **PMC** defining a potential security mark **PSM** are not actual mark constituents **MC**. Of course, in such case, the potential security mark **PSM** would not be an actual security mark **SM**. Thus, to ensure that a potential security mark **PSM** is an actual security mark **SM**, the potential security mark is subjected to a verification operation **S5** in accordance with the present invention. More particularly, for each potential security mark **PSM**, a verification sub-step **S5a-1** examines the color of each potential mark constituent **PMC** defining the potential security mark **PSM**, and determines if the color of each potential mark constituent is sufficiently close to or uniform with the color of the other potential mark constituents **PMC** defining the potential security mark **PSM**. It is preferred that the potential mark constituents have a color that is equal or close to each other. For example, if two potential mark constituents **PMC** have respective colors that fall within the color range used in the binarization color-checking sub-step **S2a**, but the respective colors thereof are found at extreme opposite ends of the acceptable color range, such potential mark constituents will not be deemed to exhibit sufficient color uniformity relative to each other to be actual mark constituents **MC**. Any potential security marks **PSM** not satisfying the color uniformity verification sub-step **S5a-1** are discarded by the sub-step **S5c**.

[0036] For potential security marks **PSM** satisfying the color uniformity verification sub-step **S5a-1**, a dimensional uniformity verification sub-step **S5a-2** examines the potential mark constituents **PMC** for dimensional uniformity relative to each other. The dimensional uniformity verification sub-step **S5a-2** examines the column width and/or row height of each potential mark constituent **PMC** defining the potential security mark **PSM** for purposes of ensuring that the dimensions of the potential mark constituents are consistent relative to each other. Again, for example, if one potential mark constituent **PMC** exhibits dimensional characteristics relative to other potential mark constituents that vary by +/- 5%, the potential mark constituent will fail the dimensional uniformity verification sub-step **S5a-2**, and the sub-step **S5c** will discard the relevant potential security mark **PSM**. If the potential mark constituents **PMC** defining a potential security mark **PSM** satisfy the verification operation **S5**, a sub-step **S5B** identifies the potential security mark **PSM** as an actual security mark **SM**.

[0037] Subsequent to the verification operation **S5**, a prevention operation **S6** operates to prevent effective reproduction of the document scanned by the image input scanner **12**. A sub-step **S6a** determines if an actual security mark **SM** has been identified as present in the document being scanned by the input scanner **12**. If no security mark **SM** has been found, reproduction of the document is permitted. If, on the other hand, a security mark **SM** is identified, a prevention sub-step **S6b** prevents effective duplication of the document scanned by the input scanner **12**. This is accomplished using one or more suitable prevention operations such as disabling the image output device **16**, not sending output data from the image processing unit **14** to the image output device **16**, embedding or otherwise including a message (such as VOID) in the image data sent to the image output device **16** so that the message is visible in the document reproduction, or by any other suitable method that prevents an effective reproduction of the document scanned by the input scanner **12**.

Claims

1. A method of digital image processing comprising:

(a) for a printed document potentially including a security mark defined therein by a plurality of actual mark constituents each having a select color, size, and shape and having a select spatial arrangement relative to each other, scanning said document to obtain digital image data corresponding to said printed document, said digital image data defined in terms of a plurality of color input pixel values;
(b) processing said digital image data to identify all portions representing potential constituents of a security mark;
(c) for each potential mark constituent represented by said digital image data, determining if said potential mark constituent, together with at least one other potential mark constituent represented by said digital image data, defines a potential security mark;
(d) for each potential security mark represented in said digital image data, determining if said potential security mark represents an actual security mark present in said printed document.

2. A digital image processing method for preventing unauthorized reproduction of a printed document including a security mark defined in terms of a plurality of actual mark constituents having a select color, select dimensions and arranged in a select pattern relative to each other, said method comprising:

a. scanning said printed document to derive color digital data representing said printed document, said color digital data defined in terms of a plurality of pixels each having a color value;
b. identifying all pixels of said color digital data having a color value representing a color at least approximating said select color of said plurality of actual mark constituents;
c. constructing a binary map of said color digital data defined in terms of "on" and "off" pixels, said "on" pixels corresponding to said identified pixels of said color digital data having color values at least approximating said select color of said plurality of actual mark constituents;
d. using said binary map, identifying potential mark constituents defined by said "on" pixels;
e. using said binary map, identifying at least one neighborhood of plural potential mark constituents together defining a potential security mark;
f. identifying said potential security mark as an actual security mark if said potential mark constituents thereof are uniform relative to each other; and
g. preventing effective duplication of said printed document if an actual security mark is identified.

3. A method of processing digital image data representing a color printed document that includes a security mark for purposes of identifying the security mark represented in said digital image data, said method comprising:

a. processing said digital image data to identify all portions thereof defining a select color corresponding to the color of the security mark in said printed document;
b. for each portion of said digital image data defining the select color, determining if the portion represents a potential constituent of a security mark in said printed document;
c. for each potential security mark constituent identified in said digital image data, determining if said potential security mark constituent, together with at least one other potential security mark constituent, defines a potential security mark in said digital image data;
d. comparing the potential security mark constituents defining each potential security mark to each other to determine if they are uniform in terms of color and size relative to each other; and
e. identifying a potential security mark as a security mark represented in said digital image data if the potential security mark constituents of said potential security mark are sufficiently uniform in terms of the least color and size relative to each other.

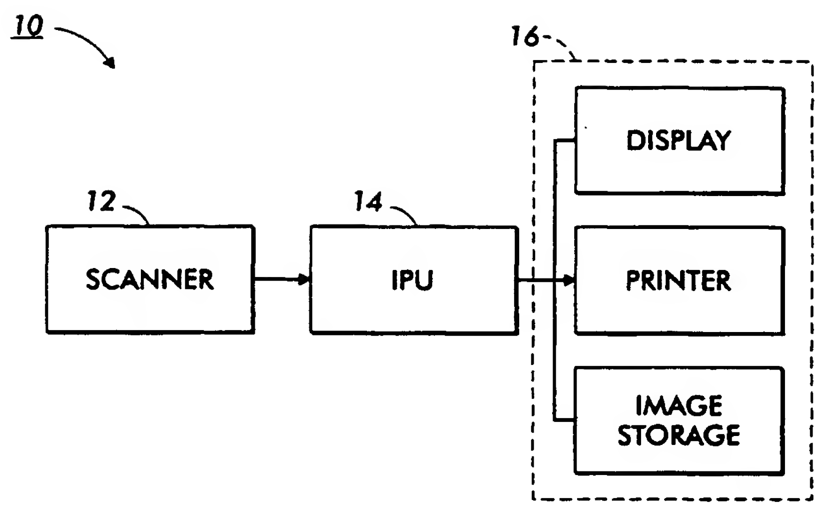
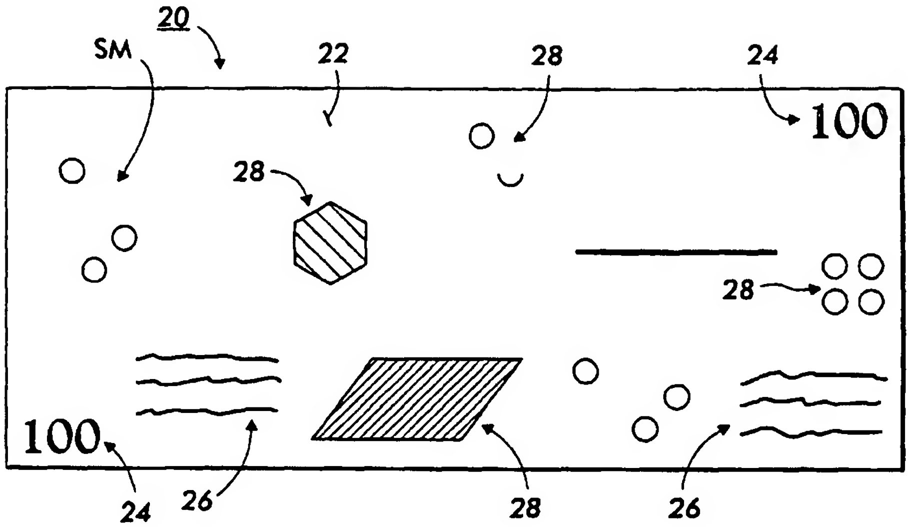


FIG. 1

FIG. 2A



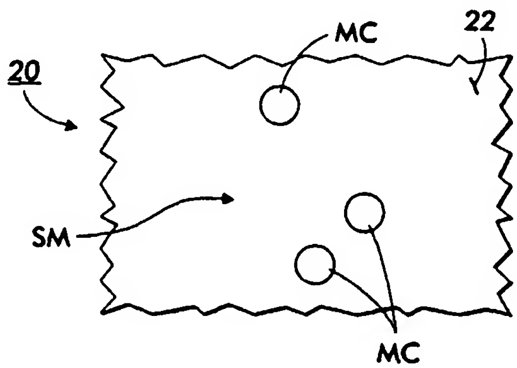


FIG. 2B

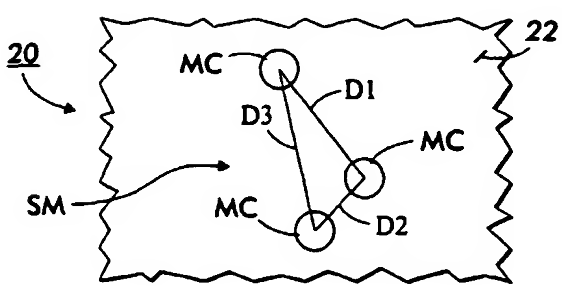


FIG. 2C

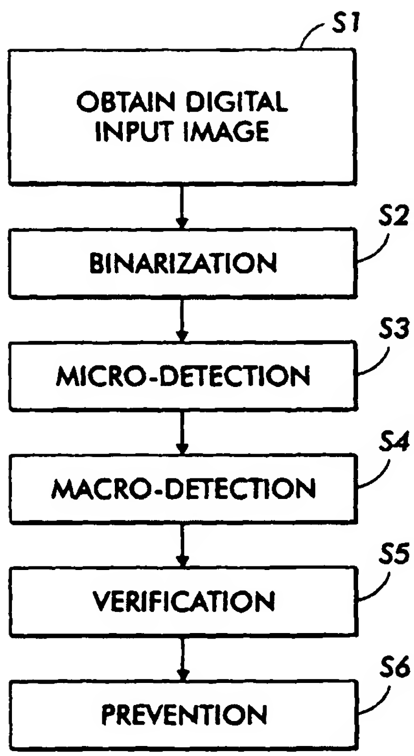

S1
OBTAIN DIGITAL INPUT IMAGE
S2
BINARIZATION
S3
MICRO-DETECTION
S4
MACRO-DETECTION
S5
VERIFICATION
S6
PREVENTION

FIG. 3

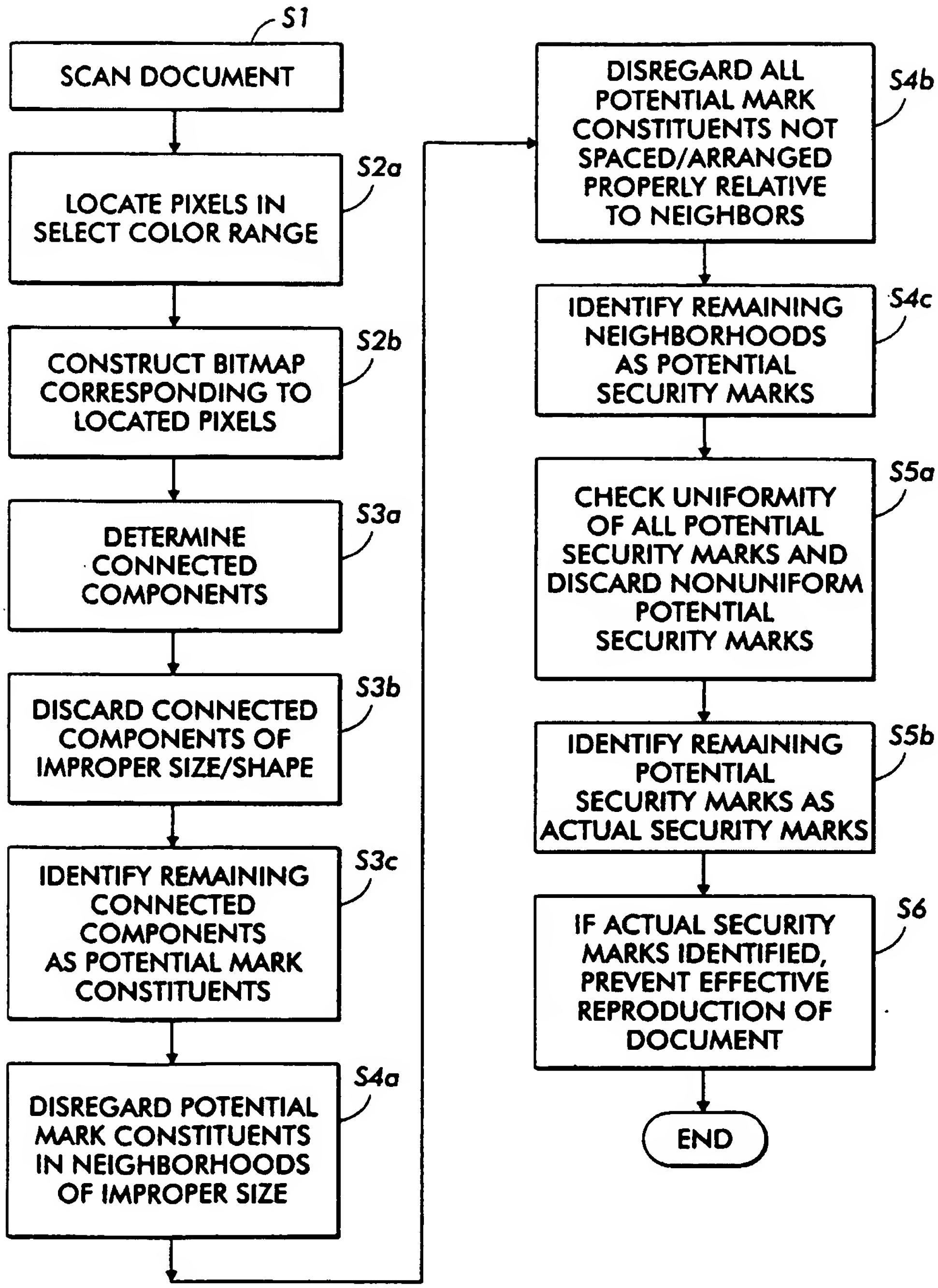
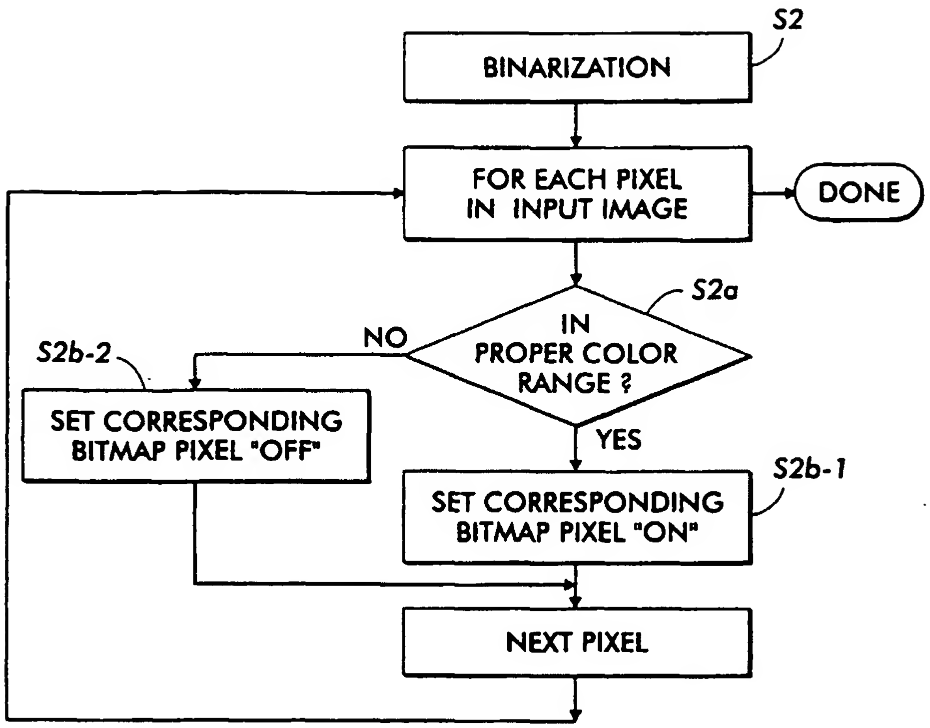

S1
SCAN DOCUMENT
S2a
LOCATE PIXELS IN SELECT COLOR RANGE
S2b
CONSTRUCT BITMAP CORRESPONDING TO LOCATED PIXELS
S3a
DETERMINE CONNECTED COMPONENTS
S3b
DISCARD CONNECTED COMPONENTS OF IMPROPER SIZE/SHAPE
S3c
IDENTIFY REMAINING CONNECTED COMPONENTS AS POTENTIAL MARK CONSTITUENTS
S4a
DISREGARD POTENTIAL MARK CONSTITUENTS IN NEIGHBORHOODS OF IMPROPER SIZE
S4b
DISREGARD ALL POTENTIAL MARK CONSTITUENTS NOT SPACED/ARRANGED PROPERLY RELATIVE TO NEIGHBORS
S4c
IDENTIFY REMAINING NEIGHBORHOODS AS POTENTIAL SECURITY MARKS
S5a
CHECK UNIFORMITY OF ALL POTENTIAL SECURITY MARKS AND DISCARD NONUNIFORM POTENTIAL SECURITY MARKS
S5b
IDENTIFY REMAINING POTENTIAL SECURITY MARKS AS ACTUAL SECURITY MARKS
S6
IF ACTUAL SECURITY MARKS IDENTIFIED, PREVENT EFFECTIVE REPRODUCTION OF DOCUMENT
END

FIG. 4

FIG. 5A


S2
BINARIZATION
FOR EACH PIXEL IN INPUT IMAGE
DONE
S2a
IN PROPER COLOR RANGE ?
NO
S2b-2
SET CORRESPONDING BITMAP PIXEL "OFF"
YES
S2b-1
SET CORRESPONDING BITMAP PIXEL "ON"
NEXT PIXEL

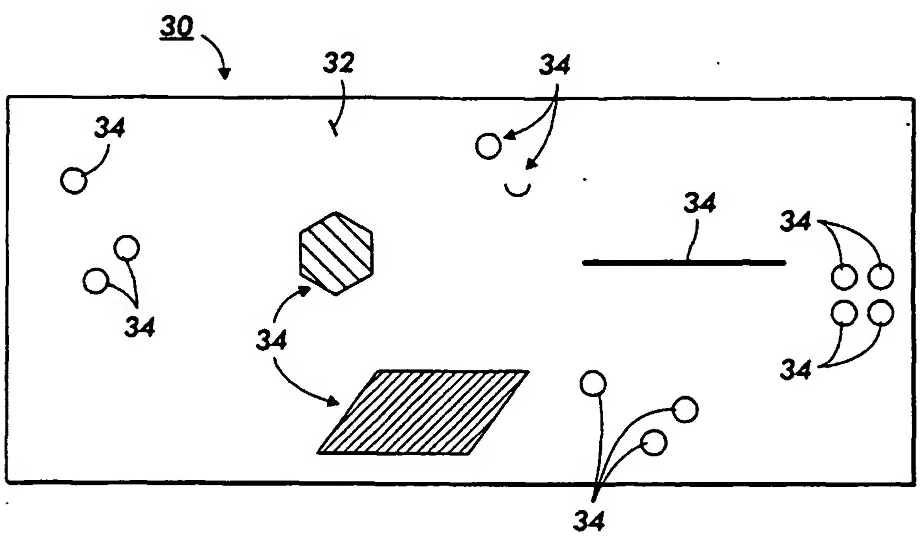
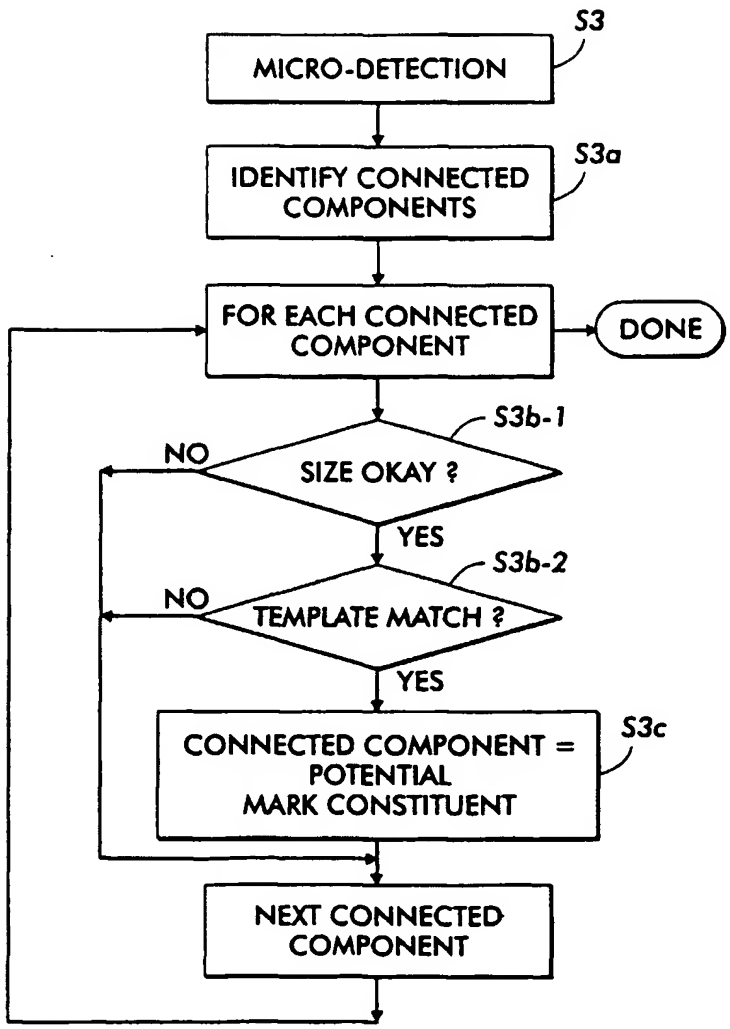

30
32
34

FIG. 5B

FIG. 6A


S3
MICRO-DETECTION
S3a
IDENTIFY CONNECTED COMPONENTS
FOR EACH CONNECTED COMPONENT
DONE
S3b-1
NO
SIZE OKAY ?
YES
S3b-2
NO
TEMPLATE MATCH ?
YES
S3c
CONNECTED COMPONENT = POTENTIAL MARK CONSTITUENT
NEXT CONNECTED COMPONENT

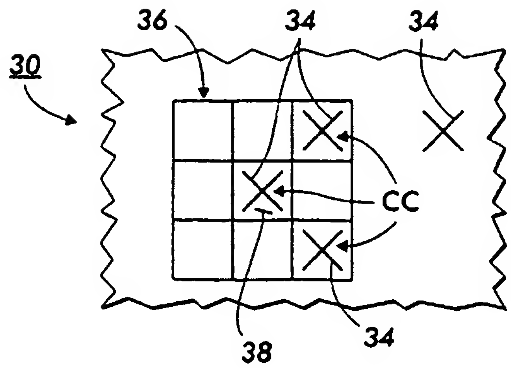


FIG. 6B

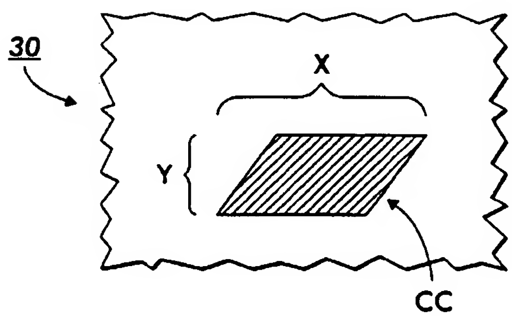


FIG. 6C

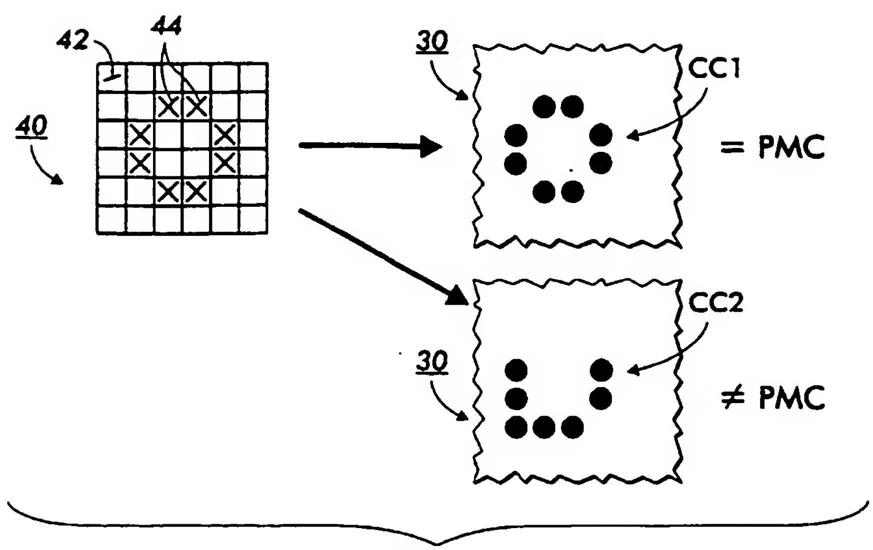


FIG. 6D

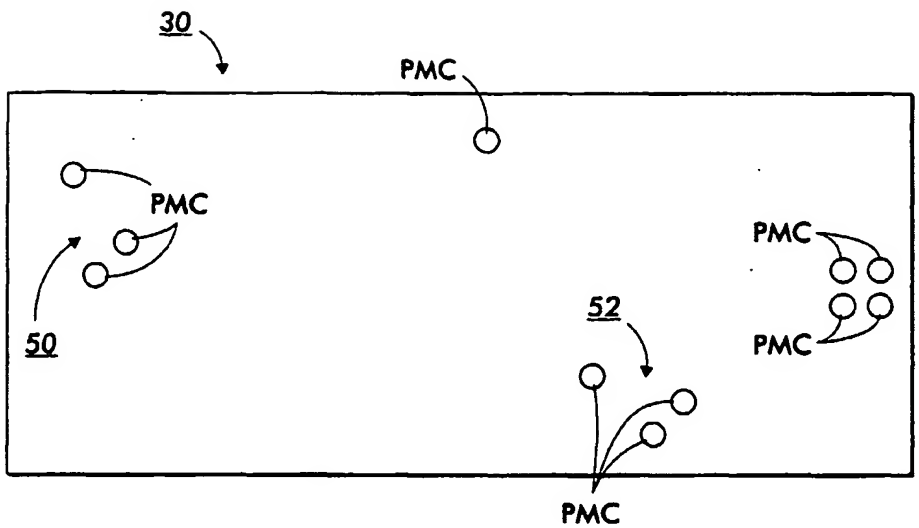
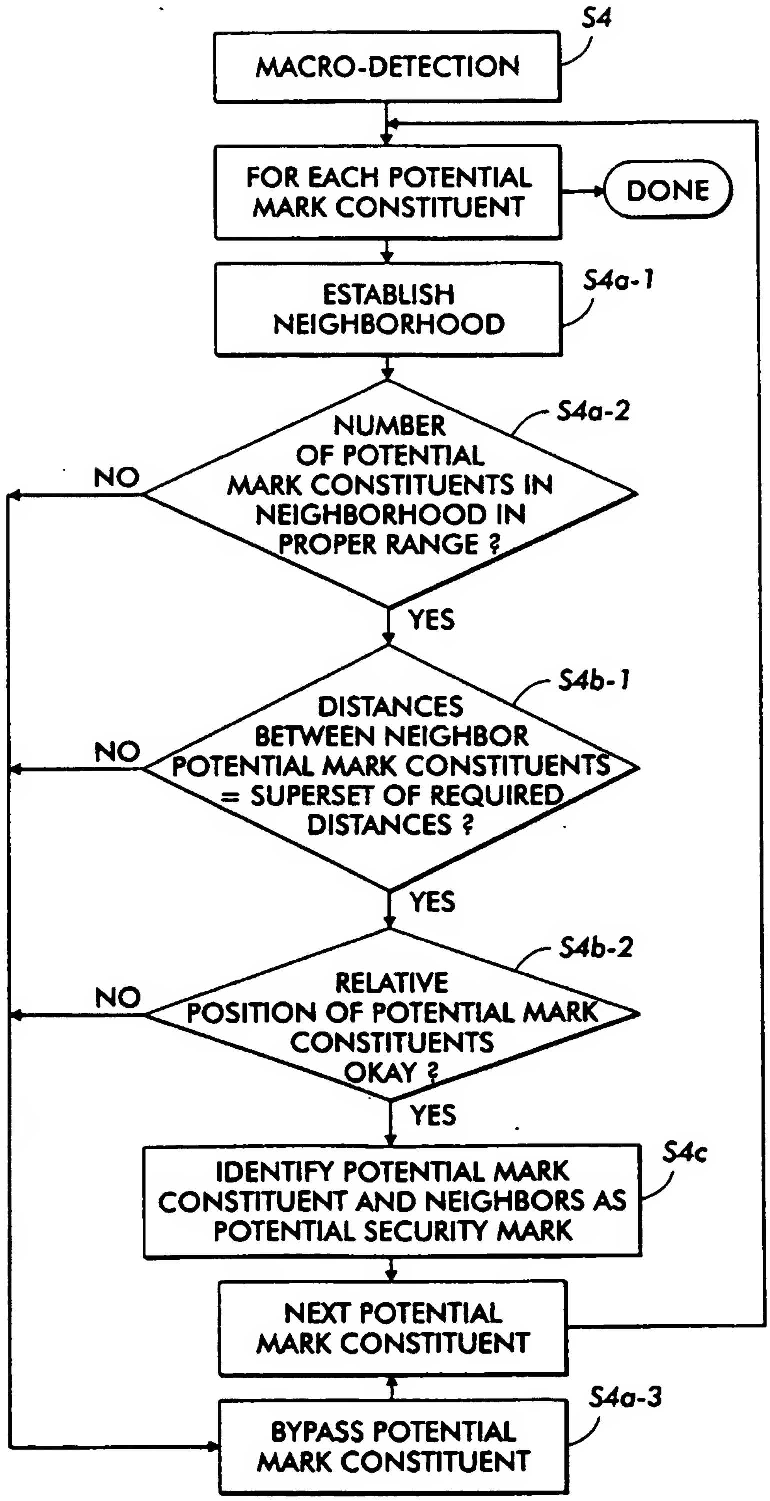


FIG. 6E

FIG. 7A


S4
MACRO-DETECTION
FOR EACH POTENTIAL MARK CONSTITUENT
DONE
ESTABLISH NEIGHBORHOOD
S4a-1
NUMBER OF POTENTIAL MARK CONSTITUENTS IN NEIGHBORHOOD IN PROPER RANGE ?
S4a-2
NO
YES
DISTANCES BETWEEN NEIGHBOR POTENTIAL MARK CONSTITUENTS = SUPERSET OF REQUIRED DISTANCES ?
S4b-1
NO
YES
RELATIVE POSITION OF POTENTIAL MARK CONSTITUENTS OKAY ?
S4b-2
NO
YES
IDENTIFY POTENTIAL MARK CONSTITUENT AND NEIGHBORS AS POTENTIAL SECURITY MARK
S4c
NEXT POTENTIAL MARK CONSTITUENT
BYPASS POTENTIAL MARK CONSTITUENT
S4a-3

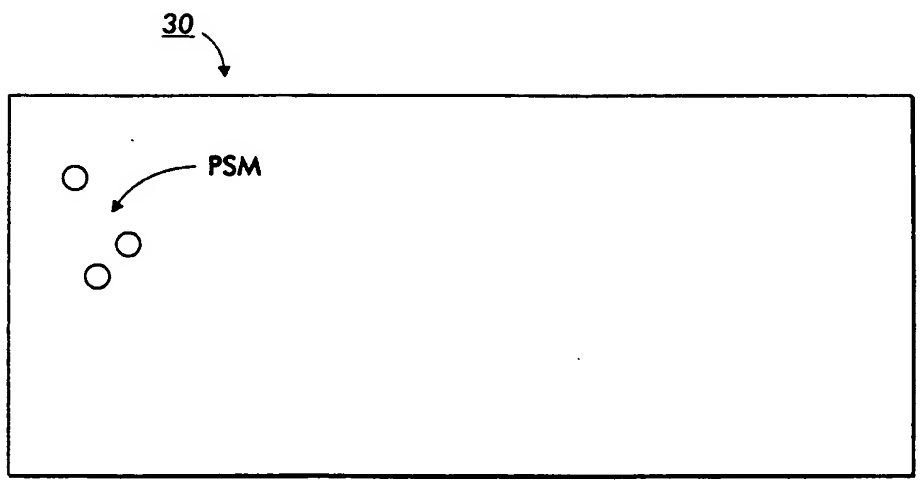


FIG. 7B

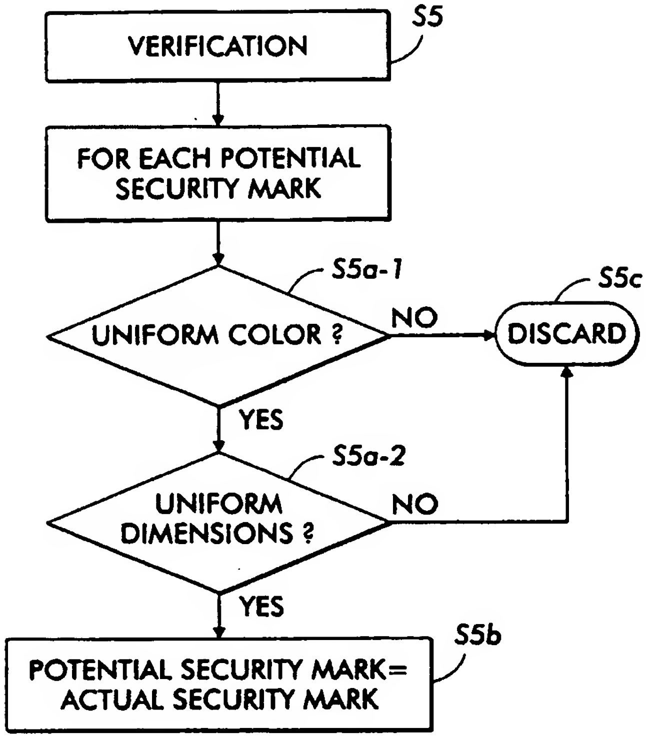

VERIFICATION
S5
FOR EACH POTENTIAL SECURITY MARK
S5a-1
UNIFORM COLOR ?
NO
S5c
DISCARD
YES
S5a-2
UNIFORM DIMENSIONS ?
NO
YES
S5b
POTENTIAL SECURITY MARK= ACTUAL SECURITY MARK

FIG. 8

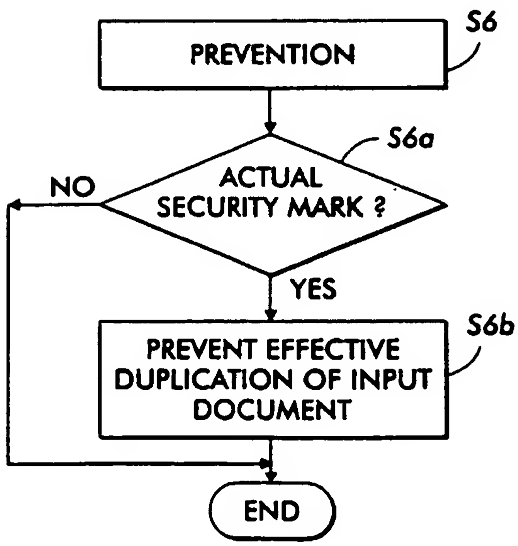

PREVENTION
S6
S6a
NO
ACTUAL SECURITY MARK ?
YES
S6b
PREVENT EFFECTIVE DUPLICATION OF INPUT DOCUMENT
END

FIG. 9